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Outline

- Abstract
- Introduction
- Tea and Health
- Mechanisms of Action
- Prevention of Cardiovascular Disease
- Prevention of Cancer

- Mouth
- Esophagus
- Stomach
- Pancreas
- Colorectal Cancer
- Skin
- Lung
- Prostate
- Urinary Bladder

- Other Health Benefits
- Potential Health Concerns Associated with Tea
- Conclusion

Graphics

- Table 1
- Table 2
- Table 3
- Table 4

Abstract

Tea is a pleasant, popular, socially accepted, economical, and safe drink that is enjoyed every day by hundreds of millions of people across all continents. Tea also provides a dietary source of biologically active compounds that help prevent a wide variety of diseases. It is the richest source of a class of antioxidants called flavonoids and contains many other beneficial compounds such as vitamins and fluoride. A growing body of evidence suggests that moderate consumption of tea may protect against several forms of cancer, cardiovascular diseases, the formation of kidney stones, bacterial infections, and dental cavities. Future research needs to define the actual magnitude of health

benefits, establish the safe range of tea consumption associated with these benefits, and elucidate potential mechanisms of action.

Introduction

The popularity of tea has stood the test of time. The drink is made from brewing leaves of the bush *Camellia sinensis* in hot water. Human ingenuity found that such leaves could be processed in different ways to provide three different kinds of brews. Green tea is derived from drying and steaming the fresh tea leaves directly after plucking. As such, no oxidation occurs. Oxidation, also referred to as fermentation, occurs naturally when tea polyphenols are complexed by contact with oxygen. Oolong tea is derived when the fresh leaves are subjected to a partial oxidation stage before drying (i.e., semidried tea leaves) and steaming. Black tea undergoes a full oxidation stage before drying (i.e., fully dried tea leaves) and steaming. Total worldwide tea production in 1996 was 2.61 million metric tons subdivided into 2.0 million metric tons of black tea (76%), 581,011 metric tons of green tea (22%), and 54,100 metric tons of oolong tea (2%).¹ The three largest producers were India (704,000 metric tons), China (560,000 metric tons), and Kenya (188,000 metric tons).¹

The *C. sinensis* bush is native to southeastern Asia and has probably been used since humans discovered how to boil water. The first historical records honor the Chinese emperor Shen Nung (2737 B.C.) for introducing tea (tea is pronounced tcha in Chinese) at his court. Since then, its consumption extended to the nonaristocratic classes in the country, to populations in neighboring countries (e.g., Japan in the 9th century A.D.), and finally overseas, thanks to Dutch traders, who introduced tea to western countries in approximately 1610.

Today, tea is enjoyed around the world and its consumption reflects local preferences and traditions. Thus, oolong tea is most widely used in China and Taiwan, and green tea is the preferred tea in many Asian and Northern African countries, whereas black tea is the choice among western consumers. The most hard-core aficionados are found in Northern Ireland (3.16 kg/person tea per year), the United Kingdom (2.53 kg/person tea per year), and Kuwait (2.52 kg/person tea per year).¹

Several factors are responsible for the popularity of tea. Tea drinking is a pleasurable experience that is enjoyed either alone or shared at social gatherings. In certain countries such as Japan, tea drinking is considered highly important, and elaborate rituals must be observed in order to serve it appropriately. In India, tea is brewed with a mix of spices (masala) for additional flavor. Tea is also considered to be safe. It is brewed by adding tea leaves to boiled water and thus provides a safe drink to millions of people for whom clean water is still a luxury. Tea does not cause intoxication. It is an inexpensive drink and is thus affordable to all social classes in all countries.

Herbal teas are not true tea because they are not derived from the leaves of *C. sinensis* but rather from other sources (e.g., blossoms of linden, leaves of peppermint, fruits of hibiscus). The original Chinese ideogram indicates that only the drink obtained from *C. sinensis* is to be considered tea. The confusion between tea and herbal tea is mostly restricted to the Germanic-derived languages (e.g., English). In other linguistic groups, for instance, within Neo-Latin languages (e.g., French), there is a clear contrast between tea and "herbal teas." The former is known as tea (thé), whereas the latter is known as an infusion (tisane). Moreover, the specific infusion is either

indicated as an infusion of a specific plant or becomes synonymous with the plant itself. An example of the first case is the brew obtained from linden flowers, which is known as "tisane de tilleul" in French. An example of the second case is the brew obtained from chamomile flowers, which in French is known as "camomille."

Tea and Health

In addition to the enjoyable, safe, and economical aspects of tea, this drink also provides a natural source of compounds that protect against a wide array of diseases. In fact, tea's medicinal properties have long been known. For centuries, people drank tea when recovering from flu and flu-like illnesses. However, it is only since the First International Symposium on Tea and Human Health, which was held in New York in 1991, that scientific research has seriously looked into the correlation between tea and the prevention of certain diseases.⁷²

The latest scientific insight into the beneficial aspects provided to tea drinkers dispelled the myth that only green tea provides health benefits. All three teas provide biologically active ingredients (e.g., flavonoids, vitamins, fluoride). Flavonoids are antioxidants, a broad class of molecules in our body that neutralize free radicals. Free radicals are potent oxidizing compounds that damage the cells. Cell damage by oxidation is implicated in the development of cardiovascular diseases and cancer. Vitamins also possess antioxidant properties and other anticarcinogenic properties. Minerals such as fluoride help fight dental cavities and osteoporosis.

The beneficial effects of tea on human health can be grouped into major and minor. In the subsequent sections, the major effects, namely those affecting cardiovascular disease and cancer, are extensively discussed. The minor effects, namely those affecting dental cavities, kidney stones, diarrhea, and immune function, are briefly discussed.

Mechanisms of Action

Research has barely scratched the surface of the potential mechanisms whereby tea confers beneficial effects to the health of consumers. Several recent review articles proposed mechanisms by which tea drinking confers protection against cardiovascular disease and cancer.^{2,3} Tea leaves are very rich in a wide variety of compounds, which are listed in Table 1. These compounds retain their biological activity upon immersion in hot water and are readily solubilized therein.⁴

Table 1. Composition of the Dry Weight (Expressed in %) of Tea Leaves

Among these compounds, flavonoids, which are a class of antioxidants, constitute the relative majority (36%) of components of the leaves of *C. sinensis*.⁵ Tea—whether black, green, or oolong—is the richest source of flavonoids in the Northern European diet, more so than regular servings of fruits or vegetables.⁶ Tea contributes approximately 63% of dietary flavonoids in the diet, whereas other dietary components such as dairy products, onions (second best at 13%), fruits (mostly grapes and apples), and wine account for the remainder.^{4,6} Because the Northern European diet closely resembles the Northern American diet, these data most likely reflect the contribution of tea to the average North American intake of flavonoids as well. The exceptional contribution of tea may

be due to the fact that 69-85% of the flavonoid content becomes soluble within the first 3-5 minutes of brewing tea in hot water.⁴ Up to an additional 19% of the flavonoids can be extracted if the same tea bag is brewed a second time.⁴ Moreover, there is some evidence that flavonoids derived from tea are more active than the homologous compounds from vegetables such as onions, spinach, and lettuce.⁷

Flavonoids first enter the digestive tract, then the cardiovascular system, and finally diffuse into several tissues.⁴ The mechanism of action of flavonoids on the digestive system is poorly understood and may be related to the absorption of flavonoids into the mucosal lining of the gastrointestinal tract. One such mode of action could account for the proven activity of flavonoids in blocking heterocyclic aromatic amines from promoting gastric and colorectal carcinogenesis.⁸

These amines are formed upon cooking meat and meat products and are considered to play a role in the development of gastric and colorectal cancers. Other intracellular mechanisms are also possible. For instance, flavonoids were shown to protect mitochondria, control the expression of oncogenes, and prevent the loss of 5-methylcytosine (i.e., DNA demethylation or hypomethylation).⁹ The last mechanism is important in protecting DNA from high rates of mutation.⁹

The effect of antioxidants on the cardiovascular system appears to be linked to several modes of action described below, or any combination thereof. Overall, there is consensus that atherosclerosis and the complications it causes are due to constriction of the diameter of arteries and/or arterioles. The constriction can be achieved by several mechanisms. Cells of the smooth muscle layer in the blood vessel may proliferate in response to growth factors released when damaged blood vessels are being repaired. Antioxidants block free radicals, thus preventing such damage and avoiding the repair mechanism that causes smooth muscle cells to proliferate.¹⁰ The second mode of action of atherosclerosis involves low-density lipoproteins (LDL) damaged by free radicals and hydroperoxides.

Macrophages are recruited in the damaged areas and engulf the damaged LDL, generating so-called fatty streaks in the blood vessel. Antioxidants have been observed to prevent LDL damage derived from hydroperoxides or other free radicals. Thus, antioxidants prevent a large number of monocytes from being recruited in the damaged areas, thereby better regulating the efflux of macrophages from the artery walls and minimizing the engulfment of LDL and the formation of fatty streaks in the blood vessel.¹⁰ The third mechanism of atherosclerosis involves the cytotoxic activity of oxidized LDL, which appears to increase platelet adherence and release growth factors promoting hyperproliferation of the smooth muscle layer of the blood vessel. Antioxidants have been shown to inhibit the cytotoxic activity of oxidized LDL.¹⁰

Besides these mechanisms of action, antioxidants have been linked to two additional risk factors implicated in cardiovascular disease. Antioxidants appear to lower cholesterol levels in normal subjects and in patients with hypercholesterolemia.¹¹⁻¹³ Antioxidants have also been observed to lower plasma or serum concentrations of homocysteine, which has been implicated in the development of cardiovascular diseases and stroke.¹⁴

Prevention of Cardiovascular Disease

Overall, cardiovascular health appears to be better among tea drinkers than non-tea drinkers.^{6,13} More specifically, the incidence of ischemic heart disease (including myocardial infarct and stroke) is lower in tea drinkers compared with

non-tea drinkers.^{6,13} The Zutphen study, conducted in the Netherlands, assessed 805 male patients during a period of 5 years.⁶ After correcting for confounding factors, which in this case were age; body weight; cholesterol level; blood pressure; degree of regular physical exercise; coffee consumption; calorie intake; and intake of [beta]-carotene, vitamins C and E, and fiber, incidence of fatal and nonfatal first myocardial infarction and mortality from stroke significantly decreased as intake of flavonoids (derived mainly from tea) increased in a dose-dependent manner.⁶ (Table 2) A follow-up to this study that looked at the risk of stroke in these patients during 15 years showed that a high intake of flavonoids (derived mainly from tea) significantly lowered the incidence of stroke compared with a low intake.⁴ The risk for developing stroke was 73% lower in the group with the highest intake of flavonoids (>28.6 mg flavonoids/day) than in the group with the lowest intake (<18.3 mg flavonoids/day).⁴

Table 2. Incidence of Myocardial Infarction and Mortality from Coronary Disease Linked to Low, Medium, and High Flavonoid Consumption

Another recent case-control study from Boston (the Boston Area Health Study) supports the protective effect of tea on cardiovascular disease.¹⁵ This study investigated the association of tea with myocardial infarction in 340 cases and age-, sex-, and community-matched controls. Extensive information obtained on coronary artery disease risk factors and average dietary intake during the previous year was accurately assessed by a 116-item semiquantitative food frequency questionnaire. Individuals drinking ≥ 1 cup of tea per day had a 44% lower risk of myocardial infarction than those drinking no tea; results were independent of known coronary artery disease risk factors.¹⁵

As discussed in the previous section, the protection conferred by flavonoids seems quite complex and may involve homocysteine, cholesterol, atherogenesis, and the protection of LDL.^{14,16,17} The findings pertaining to the effects of tea on cholesterol and homocysteine levels are of particular importance. In a prospective study, a cohort of Norwegians was divided into five groups on the basis of tea consumption.¹⁴ Nondrinkers provided the baseline levels for subsequent comparisons. The other four groups were defined as low consumers of tea (<1 cup/day), moderate consumers (1-2 cups/day), moderate-to-high consumers (3-7 cups/day), and high consumers (>8 cups/day). Plasma cholesterol levels were inversely correlated with tea consumption; serum cholesterol concentrations were decreased by 6%, 12%, 19%, and 28%, respectively, in the four groups compared with non-tea drinkers.¹⁴ The effect of tea on plasma homocysteine levels was slightly different. The low consumers had a 6% reduction, moderate consumers a 20% reduction, and moderate-to-high consumers a 31% reduction, whereas high consumers had a 9% increase in plasma homocysteine concentrations compared with non-tea drinkers.¹⁴ Other human studies showed that tea drinking lowers cholesterol concentrations in normal subjects and in patients with hypercholesterolemia.^{11-13,18} The human data were confirmed by an animal study. Hara¹⁶ reported that the polyphenols in tea (mainly catechins and theaflavins) lowered hypercholesterolemia to normal levels, reduced blood pressure, and decreased the risk of stroke in susceptible rats.

Another study from Norway studied the relationship between black tea consumption and serum cholesterol concentration, systolic blood pressure, and mortality from all causes of coronary heart disease in 9856 men and 10,233 women, ages 35-49, in the county of Oppland, Norway.¹⁹ Increasing tea consumption was significantly

associated with decreased mean serum cholesterol and decreased systolic blood pressure. The mortality rate was reduced, although not statistically significantly, in persons drinking ≥ 1 cup/day compared with persons drinking no tea or ≤ 1 cup/day. In men, deaths from coronary heart disease were significantly reduced (by 40%) for tea drinkers ≥ 1 cup/day versus nondrinkers (≤ 1 cup/day).

Some human studies, however, have not shown protective effects of tea consumption on serum lipid profiles^{20,21} and coronary heart disease morbidity and mortality.²² Nevertheless, the overall picture emerging from published studies is that tea confers protective effects on the cardiovascular system. This is supported by observations that tea drinking significantly reduces the risk of ischemic heart disease and stroke as well as serum or plasma concentrations of cholesterol and homocysteine.

Prevention of Cancer

In addition to beneficial effects on the cardiovascular system, tea also appears to provide protective effects against several cancers. A recently published large prospective epidemiologic study conducted in the American Midwest suggests a beneficial effect of tea drinking on cancer. This study was conducted in a large group ($n = 35,000$) of post-menopausal women between 55 and 69 years of age in Iowa (the Iowa Women's Study).²³ These women were followed for 8 years. Although the incidence of some cancers (melanoma, breast, some respiratory tract, ovarian, and non-Hodgkin's lymphoma) seemed unrelated to tea consumption, other cancers (digestive tract, including the pancreas; gynecological, including the cervix and uterus; urinary tract; and leukemia) were inversely correlated with tea consumption.²³ This study showed that a daily intake of two or more cups of tea per day reduced the development of digestive and urinary tract cancers by 60% and 32%, respectively, compared with non-tea drinkers.²³ More specifically, there was an inverse relationship between tea drinking and cancers of the mouth, esophagus, stomach, pancreas, colorectum, bladder, and prostate.²³ In the following section, evidence from human and animal studies pertaining to the effect of tea on the development of cancer is discussed in a site-specific manner (Table 3).

Table 3. Correlation Between Specific Cancers and Tea Drinking

Mouth

Tea flavonoids were shown to be beneficial to the mucosal lining of the mouth. The incidence of superficial precancerous lesions (leukoplakia) was inversely correlated with tea flavonoids.²⁴ In one published study, 59 patients with leukoplakia were treated with either a tea extract (29 patients) or with extracts from vegetables rich in antioxidants (30 patients); there was no true placebo group in this study. The effects of the treatment were assessed after 6 months of intervention. Patients who received the tea had a significantly higher rate of leukoplakia regression compared with patients who received the vegetable extracts (37.9% versus 10.0%, $P \leq 0.05$), as illustrated in Table 4.²⁴ This study may constitute the only attempt to use tea not as a preventive means to decrease the risk of cancer but rather as a therapeutic agent against established precancerous lesions. A larger number of subjects and a true control group followed for a longer duration, however, are needed to confirm this preliminary

result.

Table 4. Leukoplakia Patients Treated with Tea Extracts Versus Vegetable
Extracts

Esophagus

A higher incidence of cancer of the esophagus was previously linked to tea consumption.³³ Recent studies, however, do not confirm this earlier finding. In fact, a large Japanese study on both green tea and black tea showed that once potential confounding factors (gender, age, year and season of first hospitalization, smoking, alcohol, regularity of physical exercise, and intake of fruit, rice, and beef) are corrected, tea drinking does not increase the development of esophageal cancer.²⁵ It now appears that the development of esophageal cancer is related to the high temperature at which the drink is consumed rather than the nature of the drink.²⁵ Thus, it was suggested that any drink consumed at hot temperatures ($\approx 60^{\circ}\text{C}$) may result in irritation of the esophagus and a higher incidence of esophageal cancer.^{25,34} In fact, a number of case-control studies found no relationship between tea consumption at normal temperatures ($37\text{-}45^{\circ}\text{C}$) and esophageal cancer, but ingestion of very hot tea ($55\text{-}67^{\circ}\text{C}$) increased risk by two- to threefold.³⁵ The increased risk for esophageal cancer associated with consumption of tea at high temperatures may be due to enhanced cell proliferation in response to cell death from scalding of the esophageal mucosa.³⁵

Stomach

Stomach cancer is relatively uncommon in North America as opposed to its high prevalence in China, Japan, Korea, and South American countries. The effects of tea on gastric malignancy appear to be conflicting. Some studies suggest an inverse relationship between tea consumption and stomach cancer, whereas others show either no correlation or a positive correlation.³⁴ Owing to the methodologic limitations, no definite conclusion can be drawn. Large prospective studies that can correct for potential confounding factors are necessary to define the relationship between stomach cancer and tea. The only such study published is the aforementioned study by Inoue et al.²⁵ The results were corrected for confounding factors (see above). Investigators concluded that there was no association between tea consumption and stomach cancer.²⁵ However, consumption of seven or more cups per day of green tea significantly decreased the risk of stomach cancer (by 31%) compared with no green tea consumption.²⁵

Pancreas

Pancreatic cancer is one of the deadliest cancers. Tea consumption was correlated to a lower incidence of pancreatic cancer in humans. A clear inverse correlation was shown by a Chinese study in which 451 cases of pancreatic cancer were compared with 1552 matched controls without pancreatic cancer.²⁶ Regular drinkers of tea experienced a 12% and 53% lower incidence of cancer among males and females, respectively, compared with non-tea drinkers.²⁶ When the intake of tea exceeded 200 g/month, the risk reduction remained unchanged among women, whereas the incidence of pancreatic cancer was further decreased by 43% in men.²⁶ This study was limited, however, by an incomplete correction of

confounding factors, including occupational risk factors. Another case-control study from Poland reported a significant reduction in risk of pancreatic cancer with increasing lifetime consumption of tea ($P \leq 0.001$).³⁶

Colorectal Cancer

Tea consumption is inversely related to the development of colorectal cancer. In a case-control study from Sweden, the protective effect of tea was observed with consumption of two or more cups per day.²⁷ The incidence of cancer was reduced by 4% in the colon, 44% in the rectum, and 21% in the colorectum compared with non-tea drinkers.²⁷ However, low tea consumption (fewer than two cups per day) offered no protective effect on the development of colorectal cancer compared with non-tea drinkers.²⁷ Evidence from another study suggests that tea exerts its protective effect in later stages of colorectal carcinogenesis because no risk reduction was observed for small adenomas, the well-established precursors of colorectal cancer.³⁷ In a recent large Chinese study, women demonstrated a greater degree of risk reduction in the development of colorectal adenoma than males at every level of tea consumption.^{26,34}

Skin

There is a lack of human studies examining the relationship between tea drinking and skin cancer. The best studies pertaining to the relationship between tea consumption and skin cancer involve work conducted in mice. Drinking tea seems to protect mice from the carcinogenic effects derived from prolonged exposure to UV light. In one such study, UV-irradiated mice (for 22 weeks) that drank tea developed 30-42% fewer keratoacanthomas and 26-33% fewer squamous cell carcinomas compared with similarly irradiated mice that drank water.²⁸

Lung

Several studies compared groups of mice treated with the tobacco-specific carcinogen 4-(methylnitrosamino)-1-(3-pyridyl)-1-butanone (NKK) and randomized to receive either water or water enriched with tea-derived antioxidants. Tea-treated mice developed 24% fewer lung tumors and the average size of the lung tumors was 38% smaller compared with the control (water-fed) mice.^{29,30} The protective effect of tea was confirmed by a subsequent study in which mice treated with the same carcinogen, NKK, were randomized to receive either water or a 2% black tea solution. Rodents fed the 2% black tea solution developed 60% fewer tumors than rodents fed water.²⁸

Prostate

The risk for prostate cancer appears to be inversely related to tea consumption. One of the few published studies was a case-control study involving three groups of tea drinkers from three different areas of Canada.³¹ The study compared non-tea drinkers with low-consumption (≤ 2 cups/day or ≤ 500 g/day) and high-consumption (≥ 2 cups/day or ≥ 500 g/day) tea drinkers. The risk of prostate cancer among non-tea drinkers was used as the baseline. A low daily consumption of tea significantly reduced the incidence of prostate cancer (by 11%) compared with non-drinkers, whereas a medium to high daily consumption of tea further reduced the incidence of prostate cancer by 70% vis-à-vis the level of the control group.³¹

Urinary Bladder

The protection conferred by tea on urinary bladder cancer appears to be more

pronounced in females than in males. Although the data are scarce, published studies report a 50% reduction in the incidence of bladder cancer in female but not in male tea drinkers compared with non-tea drinkers, even after confounding factors, such as tabagism, are taken into consideration.³² However, tea appears to improve 5-year survival in male patients with bladder cancer; male tea drinkers had twofold higher 5-year survival rates than non-tea drinkers.³⁴

Other Health Benefits

Tea contains 0.1 mg fluoride/cup.³⁸ Thus, potential health benefits associated with fluoride, which prompted North American health authorities to add this element to potable water supplies, can be expected from drinking tea.^{38,39}

Tea also plays a role in the prevention of kidney stones. A recent study of 1750 women followed for 5 years⁴⁰ showed that the consumption of beverages rich in antioxidants drastically reduced the risk of developing kidney stones. Thus, red wine, which is a very rich source of antioxidants, albeit different from those found in tea, provided a 45% reduction when drunk in moderation (1 glass/day). Tea in the amount of 2-3 cups/day also lowered the relative risk of developing kidney stones, by 31%.⁴⁰

Tea may have antimicrobial properties; it was suggested that microorganisms that cause diarrhea are affected by tea.⁴¹ It is possible that tea's antimicrobial mechanism involves a chelating action on iron rather than a bactericidal activity against the intestinal flora (the relationship between tea and iron adsorption is discussed below). In addition, one study implicated tea as an immune system enhancer.⁴² Obviously, more work needs to be done to clarify these provocative relationships.

Potential Health Concerns Associated with Tea

There are three main issues that must be clarified before promoting tea for human health. These issues are the role of caffeine in tea, the iron-chelating activity of tea, and the high content of aluminum in tea leaves.

The average daily consumption of caffeine by North American adults is estimated to be 186-238 mg/day and is derived from coffee (60%), tea (30%), and a mix of other sources such as cola drinks, chocolate, and drugs (10%).⁴³ Whereas the concentration of caffeine in tea can vary considerably depending on blend and strength of brew, a cup of tea (170 mL) contains 25.5-34 mg of caffeine,^{44,45} i.e., roughly one-third of the caffeine found in an equal amount of coffee. The degree of caffeine consumption associated with tea drinking is well within the limits of Canada's Food Guide to Healthy Eating,^{46,47} which indicates that an excess of 400-450 mg caffeine/day may pose some risks. The proposed upper level of safe daily caffeine intake represents the average intake from 10-12 cups of tea.⁴³ Therefore, normal tea consumption does not appear to pose any risk associated with caffeine exposure.

Although some concerns regarding the effects of caffeine on osteoporosis have been raised, it is now established that caffeine does not promote osteoporosis as shown by a study in which bone mineral measurements of three groups of menopausal women were compared.⁴⁸ There was no difference among the groups with a low caffeine consumption, a moderate caffeine consumption, and a high caffeine consumption.⁴⁸ A control group, which consumed no caffeine, however, was not included in this study. Caffeine has not been linked to cancer risk; there is no statistically significant difference in the incidence of cancer between high-caffeine consumers and no-caffeine consumers.^{49,50} In some instances,

caffeine consumption was shown to reduce colorectal cancer risk.⁵¹ Although the association between caffeine consumption and the risk of cardiovascular disease has been suggested in some epidemiologic studies, recent large epidemiologic studies and meta-analyses found no evidence of this putative association.^{52,53} Teratogenic effects associated with caffeine in humans are observed with consumption of greater than 50 mg/kg of body weight.⁴⁴ Thus, for an adult weighing 70 kg, these effects would be observed with consumption of 3500 mg caffeine/day, i.e., approximately 100 cups of tea/day. Although a link between caffeine and malformation in fetuses was not unequivocally proven, there are some concerns that a fetus may be affected by excessive caffeine consumption.⁵⁴ Caffeine is lipolytic and crosses the lipid bilayer of cells; it will therefore cross the placenta and reach the fetus. Caution should therefore be exercised by pregnant women; they may want to reduce their consumption of caffeine. Human population studies and animal studies have not shown any evidence that caffeine, when consumed in moderation, causes intrauterine growth retardation, low birth weight, preterm birth, spontaneous abortion, or birth defects.^{55,56}

Consumption of tea has been shown to decrease iron absorption in the gastrointestinal tract. Polyphenols in tea are believed to form insoluble complexes with iron within the gastrointestinal tract and render the iron unavailable for absorption.

It was demonstrated that polyphenols in tea reduce the bioavailability of nonheme iron when consumed with meals.^{57,58} Dietary iron exists in two forms: heme iron and nonheme iron (inorganic iron). Heme iron is better absorbed than nonheme iron and is derived from animal foods (meat, fish, poultry, and eggs). However, tea only inhibits iron absorption when it is consumed simultaneously with foods containing nonheme iron. Tea drinking between meals, therefore, has no effect on iron absorption. In addition, the chelating activity of tea is inhibited by the presence of ascorbic acid.⁵⁹⁻⁶¹ The probable cause resides in the lower pH of the drink, which would affect the charges at the binding sites of chelators in tea, thereby rendering them inoperative. Inhibition of the chelating activity of tea also can be achieved by adding milk.⁶² This is probably because milk is very rich in minerals and tea would first bind the milk-derived ions. Thus, the chelating activity of tea would be saturated and the drink would no longer sequester iron from food. Whereas it is clear that polyphenols in tea decrease iron absorption, it is not likely to cause iron deficiency anemia in healthy individuals consuming a well-balanced diet that includes readily available sources of heme iron. In practice, this issue only concerns people who consume little or no meat and meat products. Because tea does sequester iron, however, vegetarians should not drink it while consuming meals, in order to avoid the chelation of the iron present in the food.⁶³ Vegetarians and other people at risk for iron deficiency anemia (infants, young children, and pregnant women) should be encouraged to include plenty of iron-rich foods in their diets, drink tea between meals, and add milk or squeeze a lemon wedge in their tea to increase ascorbic acid content.

The third concern regarding tea stems from the high level of aluminum in tea leaves.⁶⁴ Most plants do not absorb aluminum from soil; many produce a gelatinous mucilage around their roots that binds aluminum.⁶⁵ The tea plant, however, accumulates and stores aluminum as aluminum-hydroxide in epidermal cells of their leaves.⁶⁴ As such, the tea plant contains high concentrations of aluminum and has raised concern about a possible link between tea consumption and Alzheimer's disease. For most individuals, however, food is the major contributor of aluminum.⁶⁶ Beverages represent only a moderate source of aluminum to the diet. Whereas tea leaves may be high in aluminum, tea consumption

is not a major contributor of dietary aluminum.⁶⁶ Rather, foods such as processed cheese, grain products, and desserts are larger contributors of this mineral.⁶⁶

The data available thus far appear to indicate that tea is safe for two reasons. First, the incidence of Alzheimer's in individuals or countries with high tea consumption is not significantly different from that in those with lower tea consumption.^{67,68} Thus, Ireland and Turkey, where the per capita consumption of tea is 3 kg/person per year and 2.25 kg/person per year, respectively, do not have higher rates of Alzheimer's disease than Canada, where the consumption of tea is five- to sixfold lower (0.49 kg/person per year).^{67,68} The second reason relates to the physiologic absorption of aluminum by tea drinkers. Unlike flavonoids, which are readily dissolved in water, the aluminum found in tea leaves is not.⁶⁹ The quantity of this metal that can be derived from tea for absorption is minimal. Moreover, its presence in the blood continues to be minimal after drinking copious amounts of tea.⁷⁰ For instance, even when the dietary intake of aluminum from tea doubled, the plasma level of aluminum remained unchanged.⁷¹ Furthermore, much of the extractable aluminum in brewed tea is bound to large organic species such as theaflavins, thearubigins, and other polyphenolic fermentation products that are not easily absorbed from the gastrointestinal tract. Clearly, at present there are insufficient scientific data to indicate that tea consumption is associated with increased risk of Alzheimer's disease.

Conclusion

Tea seems to fit the description of an ideal component of a healthy dietary habit that can be used to promote human health. It is easily ingested, palatable, inexpensive, widely available, and tasty. Tea also appears to be safe and without significant side effects. Above all, tea is abundantly rich in antioxidants. However, research has consistently shown that no single dietary or lifestyle factor can provide the "magic bullet" to prevent chronic diseases such as cancer and cardiovascular disease. Tea may be used together with a variety of other foods and drinks as part of a healthy diet to promote healthy living.

Both animal and epidemiologic studies suggest promising protective effects of tea against several diseases including cardiovascular disorders and cancer. Tea contains several important biological compounds that are effective against the development of many pathologic processes. Among these, flavonoids appear to be pivotal for the beneficial effects associated with tea in humans. They act as antioxidants and prevent tissues from being damaged by free radicals. Within cells, flavonoids block effects of known carcinogens. Flavonoids also appear to protect genes from mutagenic effects of environmental factors. All of these effects may contribute to the maintenance of the healthy state of cells. There also is preliminary evidence that tea can be used not only as a preventive agent but also as a therapeutic agent against premalignant lesions in the mouth (i.e., oral leukoplakia). More studies are needed to further elucidate the therapeutic effects of tea.

There are three main concerns vis-à-vis the consumption of tea: the role of caffeine, iron absorption by the gut, and a possible link to Alzheimer's disease. If tea consumption is less than 10-12 cups/day, the level of caffeine is within the safe boundaries (≈400-450 mg/day) suggested by Canadian Health authorities. Iron absorption is an issue for vegetarians, whose diet is restricted to iron in the nonheme form, and for individuals at risk of developing iron deficiency anemia. These people should not drink tea with meals because the iron in the food is chelated by the tea. Alternatively, they can

drink tea between meals. Drinking orange or grapefruit juice with tea or adding lemon or milk to the tea would obviate the iron-sequestering ability of tea. The fear of developing Alzheimer's disease as a result of drinking tea rests on the sole fact that tea leaves are rich in aluminum. Drinking tea, however, does not increase the level of aluminum in the plasma, a necessary condition for aluminum to accumulate in human tissues. There is no evidence to support the role of tea in the pathogenesis of Alzheimer's disease.

The image tea has gained through the centuries is one of pleasure, which can be beneficial at times of illness such as flu and flu-like diseases. Current scientific research has reinforced this perception, shedding some light on the extent of the benefits tea can provide to humans and the mechanisms by which it provides these benefits. Unlike self-indulgent pastimes, drinking tea contains approximately zero calories (which would come from either added sugar or milk), has less caffeine than coffee on a per cup basis, has no significant side effects, and provides several health benefits.

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